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D Y & CO

Request for a grant of a patent

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The Patent Office

Cardiff Road
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1. Your reference — P009760GB

2. Patent application number
(The Patent Office will fill in this part) — 07 DEC 2000 **0029857.0**

3. Full name, address and postcode of the or of each applicant
(underline all surnames)

SONY UNITED KINGDOM LIMITED
THE HEIGHTS
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WEYBRIDGE
SURREY
KT13 0XW

Patents ADP number *(if you know it)* 06522700003

If the applicant is a corporate body, give the country/state of its incorporation — UNITED KINGDOM

4. Title of the invention — APPARATUS FOR DETECTING AND RECOVERING DATA

5. Name of your agent *(if you have one)* — **D YOUNG & CO**

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

21 NEW FETTER LANE
LONDON
EC4A 1DA

Patents ADP number *(if you know it)* — **59006**

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	Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*
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2nd			
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and filing date of the earlier application

Number of earlier application	Date of filing (day/month/year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
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Claim(s)	6
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11. I/We request the grant of a Patent on the basis of this application.

Signature D Young & Co — Date

D YOUNG & CO
Agents for the Applicants

6 Dec 2000

12. Name and daytime telephone number of person to contact in the United Kingdom — Dr Jonathan DeVile — 023 80719500

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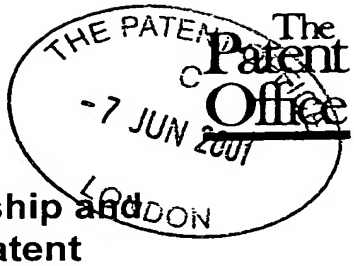

D YOUNG & CO

Statement of inventorship and of right to grant of a patent

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference	P/009760GB
2. Patent application number *(if you know it)*	0029857.0
3. Full name of the or of each applicant	SONY UNITED KINGDOM LIMITED
4. Title of the invention	APPARATUS FOR DETECTING AND RECOVERING DATA
5. State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent	BY VIRTUE OF ASSIGNMENTS DATED 20 APRIL 2001 BETWEEN OURSELVES AND THE OVERNAMED INVENTORS
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Signature Date

D Young & Co 6 Jun 2001

D YOUNG & CO
Agents for the Applicants

8. Name and daytime telephone number of person to contact in the United Kingdom: 020 7353 4343 Dr Jonathan DeVile

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DUPLICATE

APPARATUS FOR DETECTING AND RECOVERING DATA

Field of Invention

The present invention relates to methods and apparatus for detecting and recovering data embedded in information material.

Information material as used herein refers to and includes one or more of video material, audio material and data material. Video material in this context may be still images or moving images.

Background of Invention

Steganography is a technical field relating to the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

Watermarks are data embedded in material such as video material, audio material and data material. A watermark may be imperceptible or perceptible in the material.

A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark may identify the owner of the material.

Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

Visible watermarks are useful to allow, for example, a customer to view an image via, for example, the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the image and the mark is preferably not removable by the customer. Visible watermarks are also used to determine the provenance of the material into which they are embedded.

In US patent 5,930,369 (Cox et al), it has been proposed to embed data into material such as images to form a watermark by converting the material into the transform domain and adding the data to the image in the transform domain. For the example of images and the Discrete Wavelet Transform of these images into the transform domain, the data to be added can be combined with the wavelet coefficients of one of a plurality of sub-bands which are formed in the transform domain. Generally, the data to be embedded is arranged to modulate a predetermined data sequence such as a Pseudo Random Bit Sequence (PRBS). For example, each bit of the data to be embedded is arranged to modulate a copy of the PRBS, and this copy is then added, for example into one of the sub-bands of the image in the transform domain. The image is then converted back to the spatial domain.

If it is desired to detect and recover the embedded data from the image, the image is converted back to the transform domain and the embedded data is recovered from the sub-band in the transform domain by cross-correlating the transform coefficients in the sub-band with the Pseudo Random Bit Sequence which is known to the detecting apparatus.

Generally it is desirable to reduce to a minimum any perceivable effect that the embedded data may have on the information material such as images. However it is also desirable to increase the likelihood of correctly recovering the embedded data from the information material, in spite of errors which may introduced as a result of any processing which may be performed on the material.

Summary of Invention

According to the present invention there is provided an apparatus for detecting and recovering data embedded in information material, the data comprising a plurality of source data items each having been encoded in accordance with a systematic error correction code to produce encoded data items each comprising the corresponding source data item and redundant data, the encoded data items being embedded in the information material, the apparatus comprising an embedded data detector operable to detect and generate a recovered version of the encoded data from the information material, an error processor operable, for each of the recovered encoded data items, to determine whether the recovered encoded data item is deemed too errored, and if not,

decoding the encoded data item to generate a recovered version of the data item, a data store for storing the recovered version of the data item, and a recovery data processor operable, if the error processor determines that one of the recovered encoded data items is deemed too errored, to compare the source data item of the encoded data item with at least one other source data item from the data store, and to estimate the source data item of the errored encoded data item in dependence upon a corresponding value of the at least one other recovered data item.

The term systematic code is a term used in the technical field of error correction coding to refer to an error correction code or encoding process in which the original source data appears as part of the encoded data in combination with redundant data added by the encoding process. For a non-systematic encoding process, the input data does not appear as part of the encoded data.

Embodiments of the present invention address a technical problem of recovering data embedded in information material, when errors have been introduced into the data as a result for example of the embedding process, or as a result of processes performed on the information material in which the data is embedded. For the example of information material such as images, data is embedded into the images so that the effect of the embedded data is difficult to perceive and is as far as possible imperceptible. As such the strength with which the data is embedded is reduced to a minimum level which is still sufficient to ensure that the data can be recovered from the image. However, if the image is processed in some way, such as if the image is compression encoded, errors may be introduced into the embedded data as a result of the compression encoding process. This is because, typically an effect of compression encoding is to alter or discard components of the image. These components may be bearing the embedded data. In addition, inaccuracies as a result for example of quantization errors may be present when detecting and recovering the embedded data, further contributing to errors in the recovered data.

It is known to protect against errors by encoding data using an error correction code. Error correction encoded data typically can be used to correct a certain number of errors in each encoded data word and typically to detect a greater number of errors in each encoded data word.

Embodiments of the present invention utilise systematic codes in which the data items to be embedded appear as part of the error correction encoded form of the data items. Typically, the data items to be embedded may be correlated in some way. As such, if an encoded data item is deemed too errored and therefore not recoverable by error correction decoding, the data item may be recovered from the errored encoded data item, by comparing the data item with at least one other recovered data item, and estimating the data item in accordance with a correlation between the recovered data items.

A recovered encoded data item may be deemed too errored, if the error processor is operable to determine the number of errors in the encoded data item, and to compare the number of errors with a predetermined threshold. If the number of errors is greater than the threshold, then the encoded data item is deemed to have too many errors, which are safe to decode. Alternatively, the error correction decoding process performed by the error processor may provide an indication, as part of this process that the encoded data item cannot be recovered because there are too many errors.

Although the errored data item may be recovered from one other recovered data item, in preferred embodiments, the errored data item may be recovered by comparing the errored data item with a previous and a subsequent recovered data item. The errored data item may be recovered by interpolating between the previous and subsequent data items, if these data items are different, or replacing the value of the errored data item to be recovered with the values of the previous and subsequent data items if they are the same.

Although embodiments of the present invention find application in recovering any data items which have been error correction encoded and embedded into information material, in preferred embodiments, the data items have a plurality of data fields. Accordingly, in preferred embodiments the recovery processor may be operable to compare at least one of the data fields, for an errored encoded data item which cannot be decoded, with the corresponding field of at least one of a previous and a subsequent data item, and to replace the data field of the errored encoded data item in accordance with the corresponding data field of one of the previous and subsequent data items. The data field may be replaced with the value of the

corresponding data field of one of the previous and the subsequent data items, if the data fields of the previous and subsequent data items are the same, or may be replaced by a value determined by interpolating between the value of the corresponding data field of the previous and subsequent data items.

After replacing the data field of the encoded data item which is deemed to be too errored, the recovery processor is operable to determine in combination with the error processor whether the recovered encoded data item in which the data field is replaced is deemed to be too errored, and if not, decoding the encoded data item to form a recovered version of the data item. It is likely that the errors in the encoded data item will be distributed throughout this data item, so that by replacing the data field with a value determined from the already decoded data items, at least some of these errors may have been corrected. As such, the number of errors in the adapted encoded data item may now be a number, which can be corrected by error correction decoding. The error processor is therefore arranged to that effect of re-applying error correction to the effect of recovering the entire data item, if the encoded data item is deemed to be recoverable.

In preferred embodiments the data items may be meta data representative of the content of the information material. For example the data items may be Universal Material Identifiers (UMIDs), the data fields being the data fields of the UMIDs.

Although embodiments of the invention find application in detecting and recovering data from any information material, a particular application of the invention is in detecting and recovering data embedded in video image or audio signals.

Various further aspects and features of the present invention are defined in the appended claims.

Brief Description of the Drawings

Figure 1 is a schematic block diagram of a watermarking system;

Figure 2 is a schematic block diagram of a watermark embedder appearing in Figure 1;

Figure 3 is a schematic representation of a UMID encoded by the error correction encoder shown in Figure 2, using a systematic error correction code;

Figure 4 is a schematic block diagram of a combiner forming part of the watermark embedder shown in Figure 2;

Figure 5 provides an illustrative representation of a transform domain image with which data is combined;

Figure 6 is a schematic block diagram of a watermark decoder appearing in Figure 1;

Figure 7 is a schematic block diagram of an error correction decoder according to an embodiment of the present invention;

Figure 8 provides an illustrative representation of a process of recovering data items, performed by a recovery processor forming part of the error correction decoder shown in Figure 7;

Figures 9A and 9B are schematic block diagrams of the structure of an extended and a basic UMID respectively.

Description of Preferred Embodiments

An example embodiment of the present invention will be described with reference to a watermarking system in which data is embedded into a video image. Any type of data can be embedded into the image. However, advantageously the data embedded into the image may be meta data which describes the image or identifies some attributes of the content of the image itself. An example of meta data is the Universal Material Identifier (UMID). A proposed structure for the UMID is disclosed in SMPTE Journal March 2000. A more detailed explanation of the structure of the UMID will be described later.

Watermarking System

Figure 1 illustrates a watermarking system, generally 10, for embedding a watermark into a video image 115, and recovering and removing a watermark from the video image 115. The watermarking system 10 in figure 1 comprises an image processor 100 for embedding the watermark into the video image, and a decoding image processor 102 for detecting and recovering the watermark, and for removing or 'washing' the watermark from the video image.

The image processor 100 for embedding the watermark into the video image comprises a strength adapter 180, and a watermark embedder 120. The watermark

embedder 120 is arranged to embed the watermark into the video image 115, produced from the source 110, to form a watermarked image 125. The watermark to be embedded into the video image is formed from data 175 representing a UMID. Generally, the UMID identifies the content of the video image, although it will be appreciated that other types of meta data which identify the content or other attributes of the image can be used to form the watermark. In preferred embodiments the watermark embedder 120 embeds the UMID into the video image 115 in accordance with a particular application strength 185 from the strength adapter 180. The strength adapter 180 determines the magnitude of the watermark in relation to the video image 115, the application strength being determined such that the watermark may be recovered whilst minimising any effects which may be perceivable to a viewer of the watermarked image 125. After embedding the watermark, the image may be transmitted, stored or further processed in some way, such as for example, compression encoding the image. This subsequent processing and transmitting is represented generally in Figure 1 as line 122.

In Figure 1 the decoding image processor 102 for detecting and removing the watermark is shown as comprising a watermark decoder 140, a data store 150 and a watermark washer 130 which removes the watermark from the watermarked image 125.

The watermark decoder 140 detects the watermark from the watermarked video image and in the present example embodiment, generates a restored UMID 145 from the watermarked image 125. The watermark washer 130 generates a restored image 135, by removing as far as possible the watermark from the watermarked image 125. In some embodiments, the watermark washer 130 is operable to remove the watermark from the image substantially without leaving a trace. The restored image 125 may then be stored in a store 150, transmitted or routed for further processing.

The Watermark Embedder

The watermark embedder will now be described in more detail with reference to Figure 2, where parts also appearing in Figure 1 have the same numerical references. In Figure 2 the watermark embedder 120 comprises a pseudo-random

sequence generator 220, an error correction encoder 200, a wavelet transformer 210, an inverse wavelet transformer 250, a modulator 230 and a combiner 240.

The error correction encoder 200 receives the UMID 175 and generates an error correction encoded UMID comprising redundant data in combination with the UMID, in accordance with an error correction encoding scheme. It will be appreciated that various error correction coding schemes could be used to encode the UMID. However, in accordance with an embodiment of the present invention, the error correction code which is used by the error correction encoder 200 to encode the UMID is a systematic code. For the example embodiment the systematic code is a Bose-Chaudhuri-Hocquenghem (BCH) code providing 511 bit codewords comprising 248 source bits of the UMID and 263 bits of redundant parity bits. This is represented in Figure 3 where the UMID is illustrated as having only three data fields although as will be explained shortly these are just an example of three of the data fields which appear in the UMID. These data fields D1, D2, D3 will be used to illustrate the example embodiment of the present invention.

It will be appreciated that the present invention is not limited to any particular error correction encoding scheme, so that other BCH codes, or for example Reed-Solomon codes or convolutional codes could be used to encode the UMIDs. However, the encoding scheme should be arranged to encode the data items (UMIDs) in accordance with systematic codes, wherein the source data appears with redundant data added by the encoding scheme in the encoded form.

As shown in Figure 2 the error correction encoded UMID 205 is received at a first input to the modulator 230. The pseudo-random sequence generator 220 outputs a PRBS 225 which is received at a second input to the modulator 230. The modulator 230 is operable to modulate each copy of a PRBS, generated by the pseudo-random sequence generator 220, with each bit of the error correction encoded UMID. The encoded UMID is therefore arranged to modulate the PRBS to form a spread spectrum encoded data signal. In preferred embodiments the data is modulated by representing the values of each bit of the PRBS in bipolar form ('1' as +1, and '0' as –1) and then reversing the polarity of each bit of the PRBS, if the corresponding bit of the encoded UMID is a '0' and not reversing the polarity if the corresponding bit is a '1'. The modulated PRBS is then received at a first input of the combiner 240. The combiner

240 receives at a second input the image in which the PRBS modulated data is to be embedded. However the data is combined with the image in the transform domain.

The use of a pseudo-random bit sequence (PRBS) 225 to generate the spread spectrum signal representing the watermark data allows a reduction to be made in the strength of the data to be embedded in the image. By cross-correlating the data in the transform domain image to which the modulated PRBS has been added, a correlation output signal is produced with a so called correlation coding gain which allows the modulated data bit to be detected and determined. As such, the strength of the data added to the image can be reduced, thereby reducing any perceivable effect on the spatial domain image. The use of a spread spectrum signal also provides an inherent improvement in robustness of the image because the data is spread across a larger number of transform domain data symbols.

As shown in Figure 2, the wavelet transformer 210 receives the video image 115 from the source 110 and outputs a wavelet image 215 to the combiner 240. The image is thus converted from the spatial to the transform domain. The combiner 240 is operable to add the PRBS modulated data to the image in the transform domain, in accordance with the application strength, provided by the strength adapter 180. The watermarked wavelet image 245 is then transformed into the spatial domain by the inverse wavelet transformer 250 to produce the watermarked image 125. The operation of the combiner 240 will be explained in more detail shortly.

The skilled person will be acquainted with the wavelet transform and variants. A more detailed description of the wavelet transform is provided in for example "A Really Friendly Guide to Wavelets" by C Valens, 1999 (c.valens@mindless.com).

Although in the example embodiment of the present invention the data is embedded in the image in the wavelet transform domain, it will be appreciated that the present invention is not limited to the wavelet transform and could be added to the image using any transform such the Discrete Cosine Transform or the Fourier Transform. Furthermore the data could be combined with the image in the spatial domain without forming a transform of the image.

Combiner

The operation of the combiner 240 will now be explained in more detail. The combiner 240 receives the wavelet image 215 from the wavelet transformer 210, and the modulated PRBS from the modulator 230 and the application strength 185 from the strength adapter 180. The combiner 240 embeds the watermark 235 onto the wavelet image 215, by adding, for each bit of the modulated PRBS a factor α scaled by ± 1, in dependence upon the value of the bit. Selected parts of the wavelet image 215 are used to embed the watermark 235. Each pixel of the predetermined region of the wavelet image 215 is encoded according to the following equation:

$$X_i' = X_i + \alpha_n W_i \qquad (1)$$

Where X_i is the i-th wavelet coefficient, α_n is the strength for the n-th PRBS and W_i is the i-th bit of the PRBS to be embedded in bipolar form.

An example of the combiner is shown in Figure 4. In Figure 4 the combiner 240 is shown to receive the transform domain image from the connecting channel 215 which provides the transform domain image to a frame store 236. The frame store 236 is arranged to store a frame of transform domain data. The combiner 240 is also arranged to receive the spread spectrum encoded and error correction encoded UMID after it has been spread using the PRBS (modulated PRBS data). For this example embodiment one UMID in this error correction and spread spectrum encoded form is to be embedded in the frame of image data within the frame store 236. Thus, each encoded UMID forms an item of data which is to be embedded into each frame of image data. To this end, the frame store stores a frame of data representing the image in the wavelet transform domain. The data to be embedded is received at a combining processor 237 which combines the data to be embedded into selected parts of the wavelet transform domain image stored in the frame store 236. The combiner 240 is also provided with a control processor 238 which is coupled to the combining processor 237.

In Figure 5 an illustrative representation of a first order wavelet transform is presented. This wavelet transform is representative of a frame of the image transformed into the wavelet domain and stored in the frame store 236. The wavelet transform image WT_IMG is shown to comprise four wavelet domains representative

of sub-bands into which the image has been divided. The wavelets comprise a low horizontal, low vertical frequencies sub-band lH_1lV_1, the high horizontal, low vertical frequencies sub-band hH_1lV_1, the low horizontal, high vertical frequencies sub-band lH_1hV_1 and the high horizontal, high vertical frequencies sub-band hH_1hV_1.

In the example embodiment of the present invention, the data to be embedded is only written into the low vertical, high horizontal frequencies sub-band hH_1lV_1 and the low horizontal, high vertical frequencies sub-bands labelled hH_1lV_1.

By embedding the data in only the two sub-bands hH_1lV_1, lH_1hV_1, the likelihood of detecting the embedded data is improved whilst the effects that the embedded data will have on the resulting image are reduced. This is because the wavelet coefficients of the high horizontal, high vertical frequencies sub-bands hH_1hV_1 are more likely to disturbed, by for example compression encoding. Compression encoding processes such as JPEG (Joint Photographic Experts Group) operate to compression encode images by reducing the high frequency components of the image. Therefore, writing the data into this sub-band hH_1hV_1 would reduce the likelihood of being able to recover the embedded data. Conversely, data is also not written into the low vertical, low horizontal frequencies sub-band lH_1lV_1. This is because the human eye is more sensitive to the low frequency components of the image. Therefore, writing the data in the low vertical, low horizontal frequencies sub-band would have a more disturbing effect on the image. As a compromise the data is added into the high horizontal, low vertical frequencies sub-band hH_1lV_1 and the low horizontal, high vertical frequencies sub-bands lH_1hV_1.

Decoder

The operation of the watermark decoder 140 in the decoding image processor, will now be explained in more detail, with reference to Figure 6, where parts also appearing in Figure 1, bear identical reference numerals. The watermark decoder 140 receives the watermarked image 125 and outputs a restored version of the UMID 145. The watermark decoder 140 comprises a wavelet transformer 310, a pseudo-random sequence generator 320, a correlator 330, and an error correction decoder 350.

Optionally in alternative embodiments an analysis processor 360 may be provided as will be explained shortly.

The wavelet transformer 310 converts the watermarked image 125 into the transform domain so that the watermark data can be recovered. The wavelet coefficients to which the PRBS modulated data were added by the combiner 240 are then read from the two wavelet sub-bands hH_1lV_1, lH_1hV_1 in the reverse direction to the direction in which the data was added in the combiner 240. These wavelet coefficients are then correlated with respect to the corresponding PRBS used in the watermark embedder. Generally, this correlation is expressed as equation (2), below, where X_n is the n-th wavelet coefficient and R_i is the i-th bit of the PRBS generated by the Pseudo Random Sequence Generator 320.

$$C_n = \sum_{i=1}^{s} X_{sn+i} R_i \qquad (2)$$

The relative sign of the result of the correlation C_n gives an indication of the value of the bit of the embed data in correspondence with the sign used to represent this bit in the watermark embedder. The data bits recovered in this way represent the error correction encoded UMID which is subsequently decoded by the error correction decoder 350 using a decoding algorithm for the error correction code used by the encoder 200. Having recovered the UMID, the watermark can be removed from the video image by the watermark washer 130, by performing the reverse of the operations performed by the embedder.

Figure 7 provides a more detailed block diagram of the error correction decoder 350 in accordance with an example embodiment of the present invention. In Figure 7 the error correction encoded UMIDs which have been recovered from the video images by the correlator 335 are received from the connecting channel 345 by an error processor 400. The encoded UMIDs are also received from the connecting channel 345 by a recovery processor 404.

The error processor 400 operates to perform an error detection and/or correction process in order to attempt to recover the UMID.

It is known that an error correction code can correct a certain number of errors and detect a certain number of errors, the number of errors which can be detected

being generally greater than the number that can be corrected. Thus in general the ability of an error correction code to detect errors is greater than the ability of a decoder to correct these errors.

The number of errors in the recovered encoded UMID may be too great for the UMID to be recovered from error correction decoding. However the error processor has a facility for detecting whether error correction is possible. For the example BCH code, a decoding process for the BCH code can provide an indication that error correction is not possible, when error correction is applied.

Alternatively, the error processor 400, may first perform an error detection process, in order to detect the number of errors in the encoded UMID. If the number of errors is greater than a predetermined threshold the encoded UMID is determined to be unrecoverable because the encoded UMID has too many errors. The predetermined threshold is set to reduce the likelihood of falsely decoding an encoded UMID as a result of the number of errors being greater than the number which can be decoded by the error correction code. Typically, the threshold may be set in accordance with a compromise between a number of errors which can be corrected by error correction decoding, and reducing the likelihood of a number of errors being so large as to be incorrectly decoded.

If an encoded UMID is declared as being too errored, a control processor 406 controls the recovery processor 404 via a control channel 408 to perform a recovery process on the errored UMID to attempt to recover the UMID.

If the error processor 400 determines that the number of errors present in the encoded UMID is recoverable using error correction decoding, then the control processor 406 controls the error processor 400 to decode the encoded UMID to provide a recovered version of the UMID which is output from the output channel 145. This recovered UMID however is also stored under control of the control processor 406 within a data store 410.

Returning to the operation of the recovery processor 404, the embodiment of the present invention shown in Figure 7 utilises the nature of the systematic error correction code used to encode the UMID. As shown in Figure 3 the UMID as source data appears as part of the encoded code word. As such, the recovery processor has access to the UMID albeit in a form in which there are errors present. The recovery

processor may store the errored UMID locally until a subsequent UMID has been decoded and recovered and stored in the data store 410. Accordingly, the recovery processor may then compare the data fields of the UMID for one or both of a previous successfully decoded UMID and a subsequent successfully decoded UMID. This is represented in Figure 8 where UMID-1 and UMID+1 are representative of successfully recovered previous and subsequent UMIDs which are shown with the present UMID 0. As represented by hashed sections, the present UMID 0 is deemed not recoverable.

In order to recover the data from the UMID, the recovery processor 404 compares the values in the data field of the UMID. The UMID may include a clip ID which identifies the clip or take of the video images (clip ID) in which the UMIDs have been embedded. Accordingly, for example the first data field D1 may represent the clip ID. If the clip ID D1 is the same in UMID-1 and UMID+1, then it is likely that data field D1 of the UMID 0 which can not be recovered should be the same as the clip ID in UMID-1 and UMID+1. Therefore the recovery processor compares data field D1 of UMID-1 and UMID+1 and if these are the same it sets data field D1 of the UMID0 to this value.

At this point, the control processor may then attempt to decode the adapted encoded UMID. This is because if the number of errors still present in the encoded UMID after the first data field D1 has been replaced, is less than a number which can be correctly decoded, then the error correction code can be used to recover the UMID. If this number is less than the predetermined threshold, the adapted encoded UMID in which the data field D1 has been replaced is fed to the error processor 400. The error processor as before determines whether the encoded UMID can be recovered by error correction decoding, thereby recovering the rest of the UMID including the second and third data fields D2, D3.

Alternatively, or if the adapted encoded UMID still cannot be decoded, after having replaced the first data field D1, the second and third data fields D2 and D3 may be compared by the recovery processor 404 for the previous and subsequent UMIDs. The data field D2 may be for example a time code. As such, and because each UMID has been embedded in successive frames of the video images, it can be expected that the data in the second data field D2 will linearly increase between successive UMIDs. Therefore the recovery processor compares the second data fields D2 and if these are

different by less than a predetermined threshold then the data field D2 of the errored encoded UMID 0 is calculated by interpolating between the data values in the second data fields D2 of the previous and subsequent UMIDs. Accordingly, after replacing the second data field D2, the control processor 406 may then feed the recovered encoded UMID with the redundant data to the error processor 400 and attempt to decode the UMID once again, or simply output the UMID as recovered.

If when comparing the second data fields D2, the data fields of the previous and subsequent UMIDs differ by an amount greater than the predetermined threshold, then it may be assumed that the UMID recovered from the previous or the subsequent image frame relates to a separate video clip. As such the data field or indeed the UMID as a whole is either replaced by the corresponding field from the earlier or subsequent recovered UMIDs. In order to determine whether the previous or the subsequent UMID corresponds to the same video clip, as the UMID 0 being recovered, the content of the video images of the previous and subsequent frames are compared, with the image from which the UMID 0 is being recovered as will be explained shortly. Accordingly, the second data field D2 of the UMID to be recovered is set to the same value as the second data field D2 of the previous UMID or subsequent UMID, decoding may then be re-applied. As a default, the errored UMID can be replaced with the previous UMID.

It will be appreciated that if there exists a correlation between the values of the third data fields D3 of the recovered UMIDs, then this correlation can be used to estimate the value of the third data field D3 of the errored encoded UMID.

After all the data fields of the UMID have been estimated by interpolation or replacement, error correction decoding is again attempted on the encoded UMID. If the encoded UMID is correctable, then the encoded UMID is decoded and output as the recovered UMID. If however the UMID is still not correctable, then the UMID in the adapted form after interpolation is assumed to be correct and output as the recovered UMID. This is because the UMID may have been recovered correctly by interpolation, but because all the errors of the encoded UMID appear in the redundant parity bits, the encoded UMID is still considered to be uncorrectable by the error correction decoder.

Once a UMID has been recovered, either by error correction or by replacement and/or interpolation, then advantageously, the errored bits from the UMID in the watermarked image may be replaced. This provides a watermarked image which is essentially free from errors so that subsequent processing can utilise the watermark, and/or reproduced the watermarked image.

Other Embodiments

Returning to Figure 6, the purpose of the analysis processor 360 shown in Figure 6 will now be explained. The analysis processor is optionally provided to assist the recovery processor 404 in determining whether the data fields of the errored UMID should be replaced with the value of the data fields from the previous UMID–1 or the subsequent UMID+1 UMIDs. To this end the analysis processor 360 is arranged to compare the content of the watermarked images from which the previous and subsequent UMIDs were recovered, as well as the image from which the errored UMID was detected and recovered. The analysis processor 360 is arranged to generate signals indicative of a comparison between the content of the image from which the errored UMID was recovered with the content of the image from which the previous and/or subsequent UMIDs UMID-1, UMID+1 were recovered. The comparison can be performed by for example generating a histogram of the colour in the images. The signals representative of this comparison are fed to the recovery processor via a connecting channel 370.

The recovery processor uses the signals representing the comparison of the image content to determine whether the data fields of the errored UMID should correspond to the previous UMID-1 or the subsequent UMID+1. Accordingly, for example, where the content of the image from which the errored UMID was recovered is determined from the comparison to be more similar to the content of the image from which the previous UMID was recovered UMID-1, then the data fields of the UMID should be replaced with data values derived from the previous UMID. For example, the data field which is representative of the clip ID should be replaced with the clip ID from the previous UMID-1.

The Universal Material Identifier (UMID)

A brief explanation will now be given of the structure of the UMID, with reference to Figure 9A and 9B. The UMID is described in SMPTE Journal March 2000. Referring to Figures 9A an extended UMID is shown to comprise a first set of 32 bytes of a basic UMID, shown in Figure 9B and a second set of 32 bytes referred to as signature metadata. Thus the first set of 32 bytes of the extended UMID is the basic UMID. The components are:

•A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.

•A 1-byte length value to define the length of the remaining part of the UMID.

•A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.

•A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.

The second set of 32 bytes of the signature metadata as a set of packed metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:

•An 8-byte time/date code identifying the time and date of the Content Unit creation.

•A 12-byte value which defines the spatial co-ordinates at the time of Content Unit creation.

•3 groups of 4-byte codes which register the country, organisation and user codes.

More explanation of the UMID structure is provided in co-pending UK patent application number 0008432.7.

Various modifications may be made to the embodiments herein before described without departing from the scope of the present invention. Although in this example embodiment, the data to be embedded is added to the image in the transform

domain, in alternative embodiments the data could be represented in the transform domain, inverse transformed into the spatial domain, and added to the data in the transform domain.

CLAIMS

1. An apparatus for detecting and recovering data embedded in information material, said data comprising a plurality of source data items each having been encoded in accordance with a systematic error correction code to produce encoded data items each comprising the corresponding source data item and redundant data, said encoded data items being embedded in the information material, said apparatus comprising

an embedded data detector operable to detect and generate a recovered version of said encoded data from said information material,

an error processor operable, for each of said recovered encoded data items, to determine whether said recovered encoded data item is deemed too errored, and if not, decoding said encoded data item to generate a recovered version of said data item,

a data store for storing said recovered version of said data item, and

a recovery data processor operable, if said error processor determines that one of said recovered encoded data items is deemed too errored, to compare the source data item of said encoded data item, with at least one other source data item from said data store, and to estimate said source data item of said errored encoded data item in dependence upon a corresponding value of said at least one other recovered data item.

2. An apparatus as claimed in Claim 1, wherein said error processor is operable to determine whether each of said recovered encoded data items is errored by estimating the number of errored data symbols in each of said recovered encoded data items, and to compare said number of errors with a predetermined threshold, said recovered encoded data item being determined as errored if said number of errors is greater than or equal to said threshold.

3. An apparatus as claimed in Claims 1 or 2, wherein said recovery processor is operable to compare said source data item from said errored encoded data item with at least one of a previous and a subsequent decoded and recovered data item, and to replace said source data item of said errored encoded data item in accordance with at least one of said previous and subsequent source data items.

4. An apparatus as claimed in Claim 3, wherein said recovery processor is operable, if said previous and said subsequent source data items have the same value to replace said source data item of said errored encoded data item with the value of said previous or subsequent data items.

5. An apparatus as claimed in Claim 3, wherein said recovery processor is operable, if said previous and said subsequent source data items have different values to replace said source data item of said errored encoded data item with the value formed by interpolating between said previous and subsequent data items.

6. An apparatus as claimed in any preceding Claim, comprising an analysis processor operable to compare the content of the information material from which a plurality of recovered source data items and said errored encoded data item have been detected, and to generate data representative of the comparison, wherein said recovery processor is operable to estimate said source data item of said errored encoded data item in dependence upon said data representative of said comparison.

7. An apparatus as claimed in Claims 1, 2 or 3, wherein each of said source data items comprises a plurality of data fields, and said recovery processor is operable to compare at least one of said data fields of said errored encoded data item with the corresponding field of said at least one other recovered data item, and to replace said at least one of said fields of said errored encoded data item with the corresponding field of said recovered data item in accordance with said comparison.

8. An apparatus as claimed in Claim 7, wherein said recovery processor is operable, in dependence upon at least one of said data fields of said source data item being replaced, to determine in combination with said error processor whether said recovered encoded data item in which the data field is replaced is deemed to be too errored, and if not, decoding said encoded data item to form a recovered version of said data item.

9. An apparatus as claimed in Claims 7 or 8, wherein said recovery processor is operable, if said corresponding data field of a previous and a subsequent data items have the same value, to set said data field of said errored encoded data item to the value of one of said previous and subsequent data items.

10. An apparatus as claimed in Claims 7 or 8, wherein said recovery processor is operable, if said corresponding data field of a previous data item and a subsequent data item have different values, to replace said data field of said errored encoded data item with a value formed by interpolating between said previous and subsequent data items.

11. An apparatus as claimed in Claims 7 or 8, wherein said recovery processor is operable, to determine the difference between said corresponding data field of a previous data item and said corresponding data field of a subsequent data item, and if said difference is above a predetermined threshold to replace said data field of said errored encoded data item which cannot be decoded with the value of said field of said previous data item and otherwise to form said replacement value by interpolating between said field of said previous and subsequent data items.

12. An apparatus as claimed in Claims 7 or 8, comprising an analysis processor operable to compare the content of the information material from which a previous data item, a subsequent data item and said errored encoded data items were detected, and to generate data representative of the comparison, wherein said recovery processor is operable to replace said data field of said errored encoded data item which cannot be decoded with the value of said data field from one of said previous and said subsequent data items in dependence upon said comparison data.

13. An apparatus as claimed in Claims 6 or 12, wherein said analysis processor is arranged to estimate the content of the information material from a colour histogram or the like.

14. An apparatus as claimed in any preceding Claim, wherein said information material is at least one of video, audio, data or audio/video material, and said source data items include meta data describing the content or attributes relating to said video, audio, data or audio/video material.

15. An apparatus as claimed in Claim 14, wherein said data items include Unique Material Identifiers (UMIDs), and said data fields are the fields of said UMID, and said encoded data items are encoded UMIDs.

16. An apparatus as claimed in Claim 14 in combination with Claim 10, wherein the data field of an errored encoded UMID, which is recovered by interpolating contains data representative of the time code of said UMID.

17. An apparatus as claimed in Claim 14 in combination with Claim 11, wherein the data field of an errored encoded UMID, which is recovered by replacing the data field with data from the corresponding field of the previous encoded UMID, consequent upon a difference between the data fields of the previous and subsequent recovered UMIDs being above a predetermined threshold is representative of a clip identifier of said UMID.

18. An apparatus for embedding data into information material, said data comprising a plurality of source data items, said apparatus comprising

an error correction encoder operable to encode each of said data items in accordance with a systematic error correction code to produce encoded data items each comprising the source data item and redundant data, and

a combining processor operable to combine said encoded data items with said information material.

19. An apparatus as claimed in Claim 18, wherein said data items include meta data such as UMIDs or the like.

20. A signal representative of information material in which data have been embedded by the apparatus claimed in Claims 18 or 19.

21. A system for embedding and removing data from information material, said system comprising

an apparatus for embedding the data into the information material according to Claims 18 or 19, and

an apparatus for detecting and removing the data from the information material according to any of Claims 1 to 17.

22. A method of detecting and recovering data embedded in information material, said data comprising a plurality of source data items each having been encoded in accordance with a systematic error correction code to produce encoded data items, each encoded data item comprising the corresponding source data item and redundant data, said encoded data items being embedded in the information material, said method comprising

detecting and generating a recovered version of said encoded data items from said information material,

determining, for each of said encoded data items, whether the recovered version of said encoded data item is deemed too errored, and

if not, decoding said encoded data item to generate a recovered version of said data item, and storing said recovered version of said data item, and

if said errored encoded data item is deemed too errored, comparing said source data from said errored encoded data item with at least one other source data item from said data store, and estimating said source data item of said errored encoded data item in dependence upon a corresponding value of said other recovered data item.

23. A method of embedding data in information material, said data comprising a plurality of source data items, said method comprising

encoding each of said data items in accordance with a systematic error correction code to produce encoded data items each comprising the corresponding said source data item and redundant data, and

combining said encoded data items with said information material.

24. A computer program providing computer executable instructions, which when loaded on to a data processor configures said data processor to operate as an apparatus according to any of Claims 1 to 19.

25. A computer program having computer executable instructions, which when loaded on to a data processor causes the data processor to perform the method according to Claims 22 or 23.

26. A computer program product having a computer readable medium having recorded thereon information signals representative of the computer program claimed in any of Claims 24 or 25.

27. An apparatus as herein before described with reference to the accompanying drawings.

28. A method of detecting and recovering data embedded in an image as herein before described with reference to the accompanying drawings.

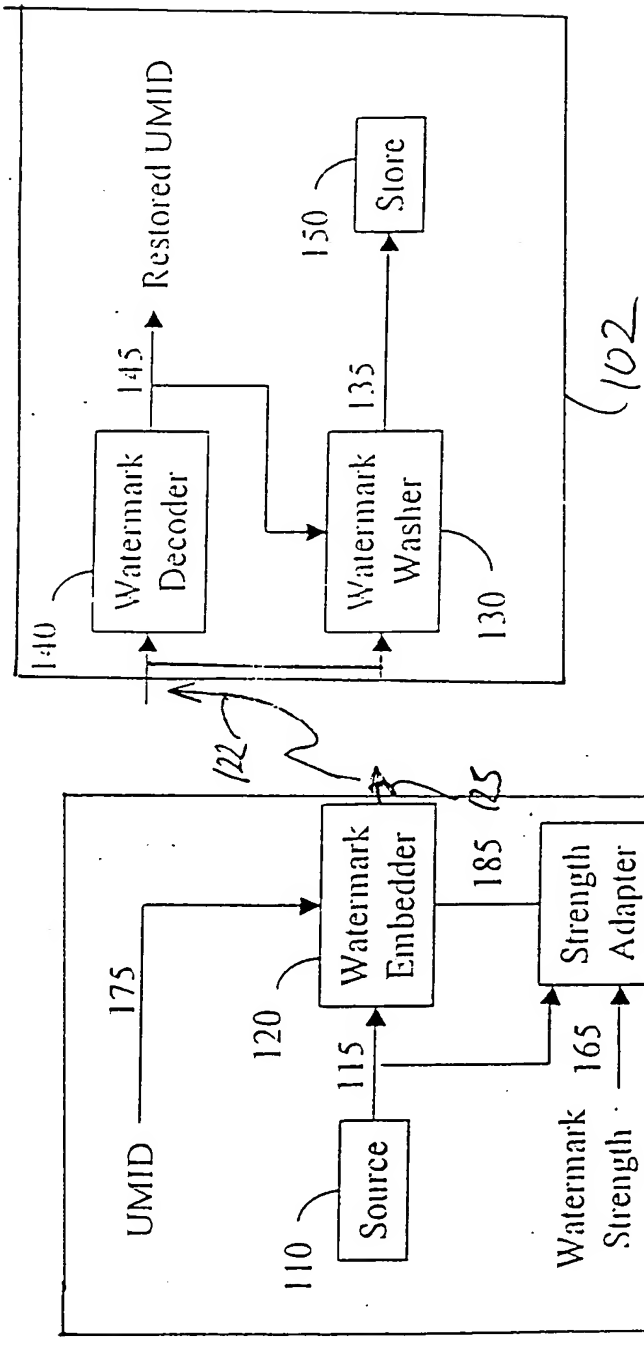
ABSTRACT

APPARATUS FOR DETECTING AND RECOVERING DATA

A system for embedding a plurality of data items in and recovering the data items from information material includes an apparatus for embedding the data comprising an error correction encoder operable to encode each of the data items in accordance with a systematic error correction code to produce encoded data items, each comprising the corresponding source data item and redundant data, and a combining processor operable to combine the encoded data items with the information material.

The system further comprises an apparatus for detecting and recovering the embedded data from the information material comprises an embedded data detector operable to detect and generate a recovered version of the error correction encoded data from the information material, an error processor operable, for each of the recovered encoded data items, to determine whether the recovered encoded data item is deemed too errored, and if not, decoding the encoded data item to generate a recovered version of the data item, a data store for storing the recovered version of the data item, and a recovery data processor operable, if the error processor determines that one of the recovered encoded data items is errored, to compare the source data item of the errored encoded data item, with at least one other source data item from the data store, and to estimate the source data item of the errored encoded data item consequent upon a corresponding value of the other recovered data item.

[Fig 7]


Restored UMID
Store
Watermark Decoder
Watermark Washer
Watermark Embedder
Strength Adapter
Source
UMID
Watermark Strength
140
145
150
135
130
122
125
175
120
115
185
165
180
110
102
100

10

Fig. 1

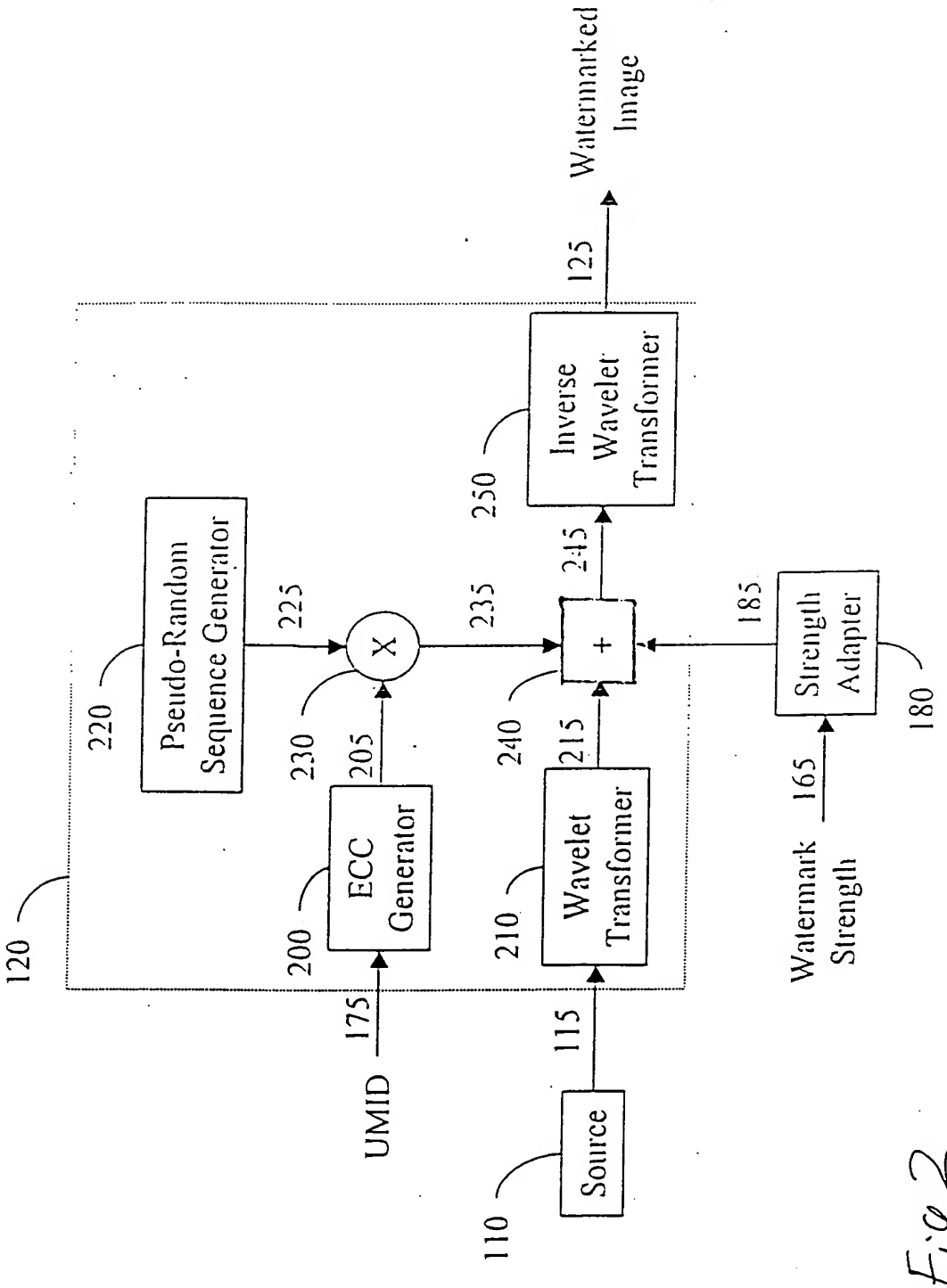

Watermarked Image
125
Inverse Wavelet Transformer
250
245
+
185
Strength Adapter
180
Watermark Strength
165
240
215
Wavelet Transformer
210
235
X
225
Pseudo-Random Sequence Generator
220
230
205
ECC Generator
200
120
175
UMID
115
Source
110

Fig 2

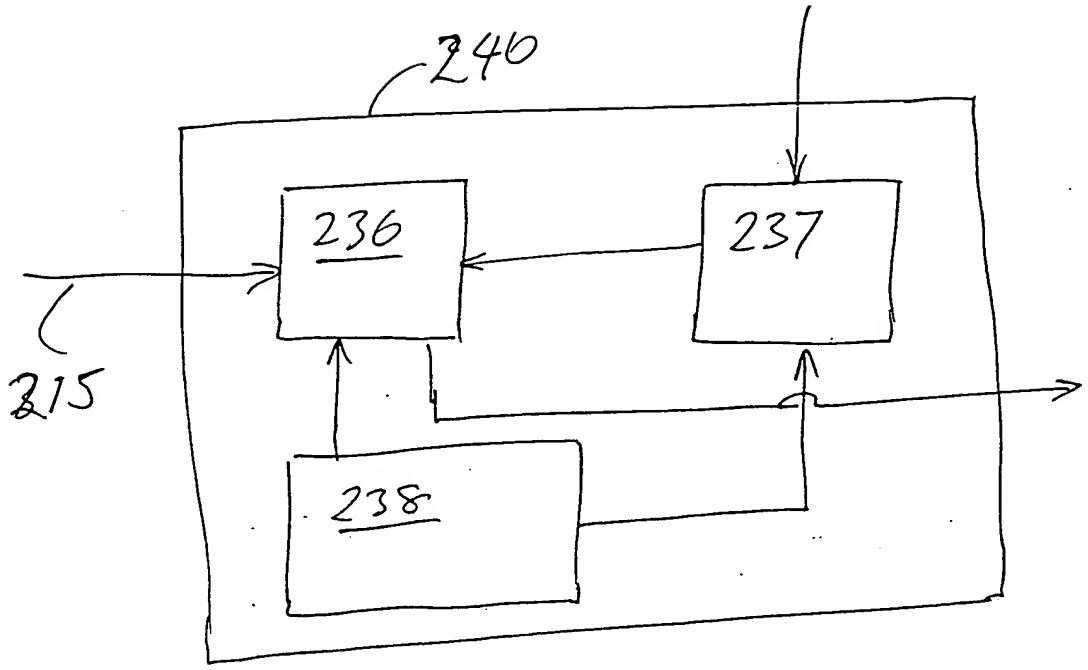


Fig. 4

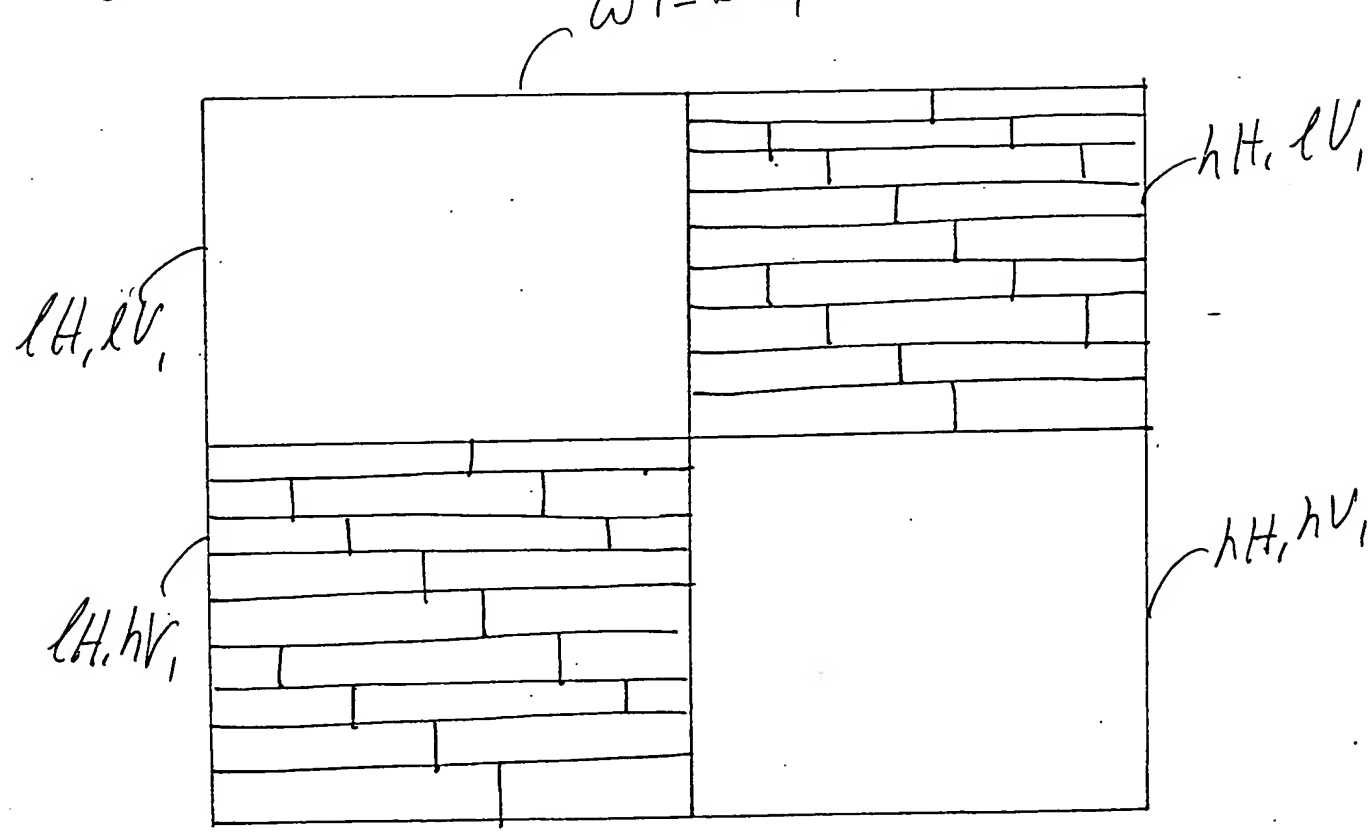


Fig. 5

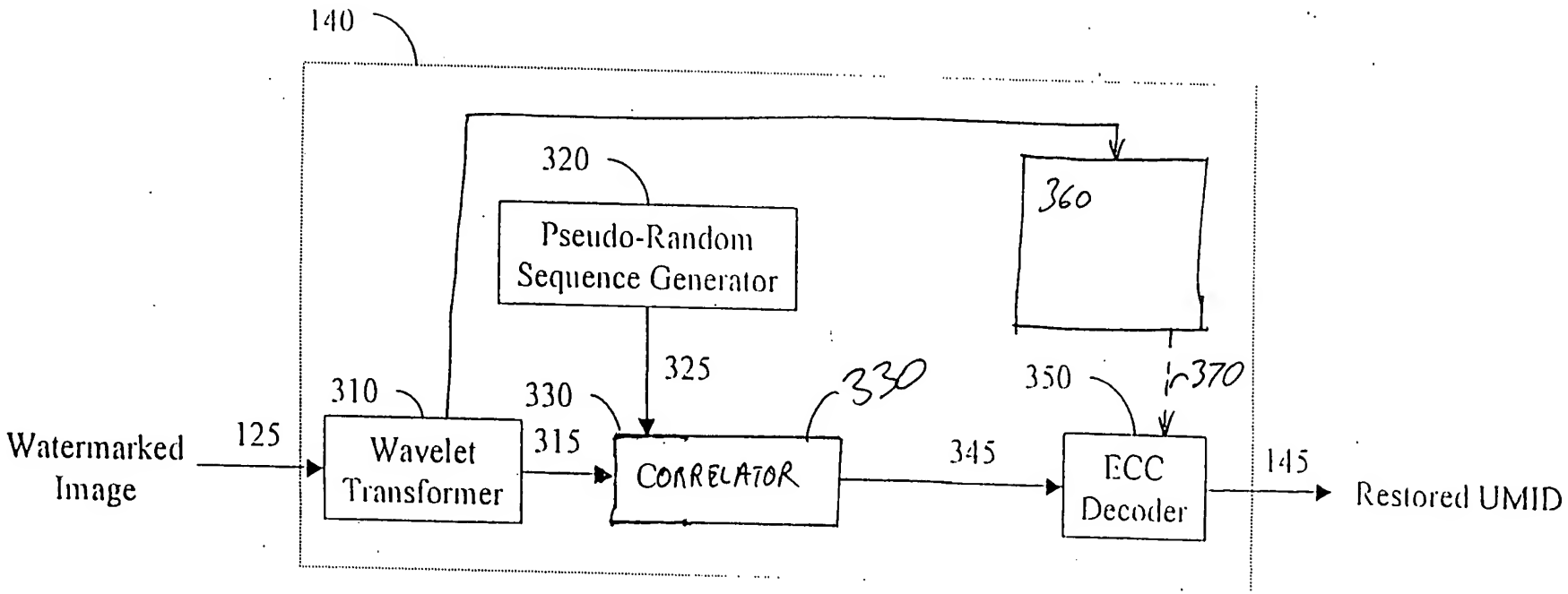

140
320
Pseudo-Random Sequence Generator
360
325
310
330
315
330
350
370
Watermarked Image
125
Wavelet Transformer
CORRELATOR
345
ECC Decoder
145
Restored UMID

Fig 6

P/9760GD

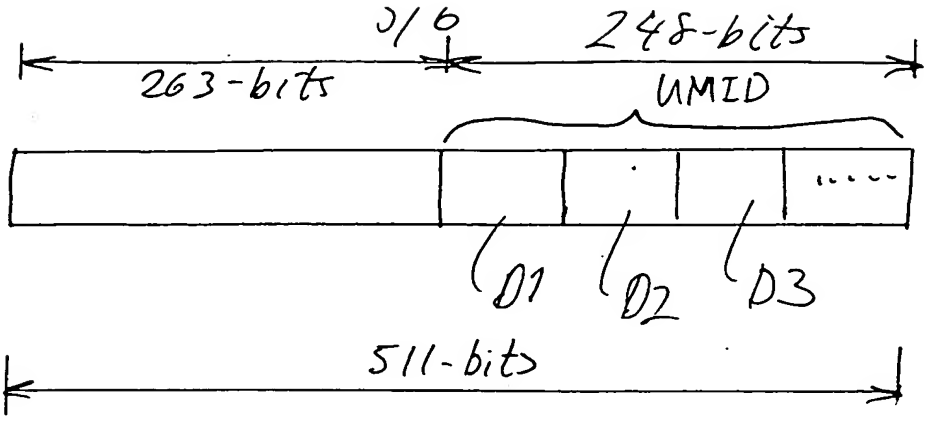


Fig. 3

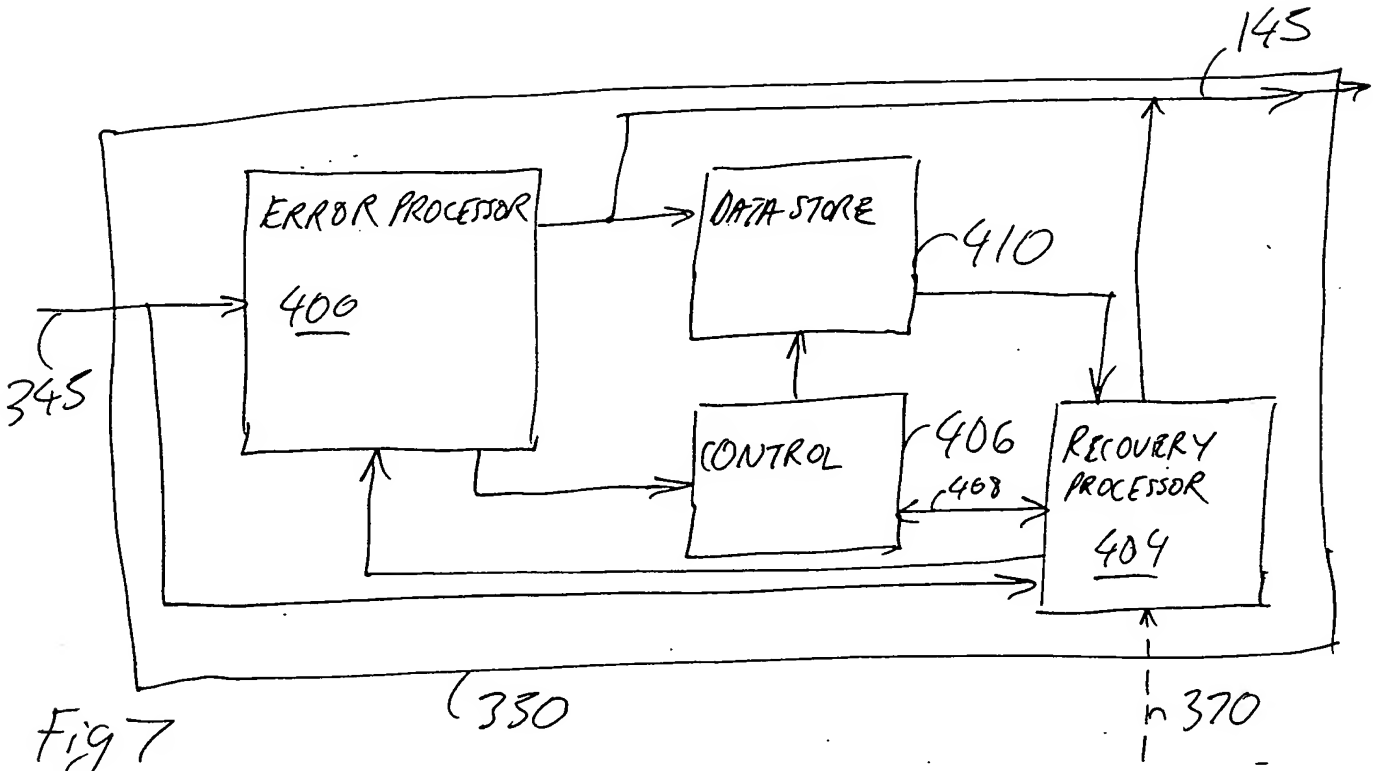


Fig 7

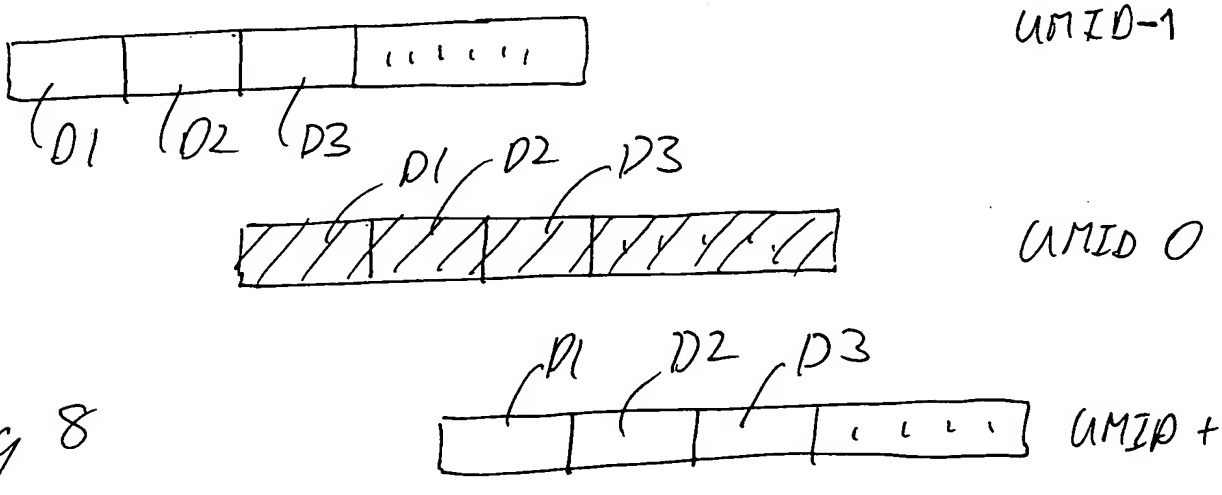


Fig 8

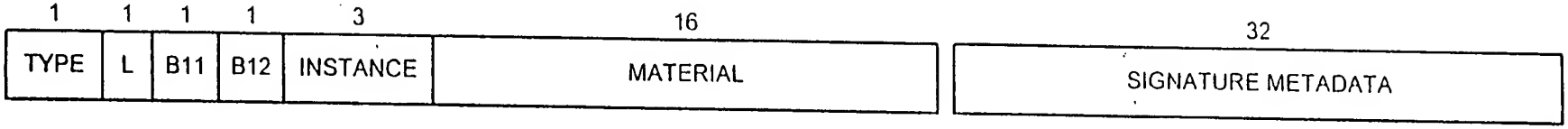
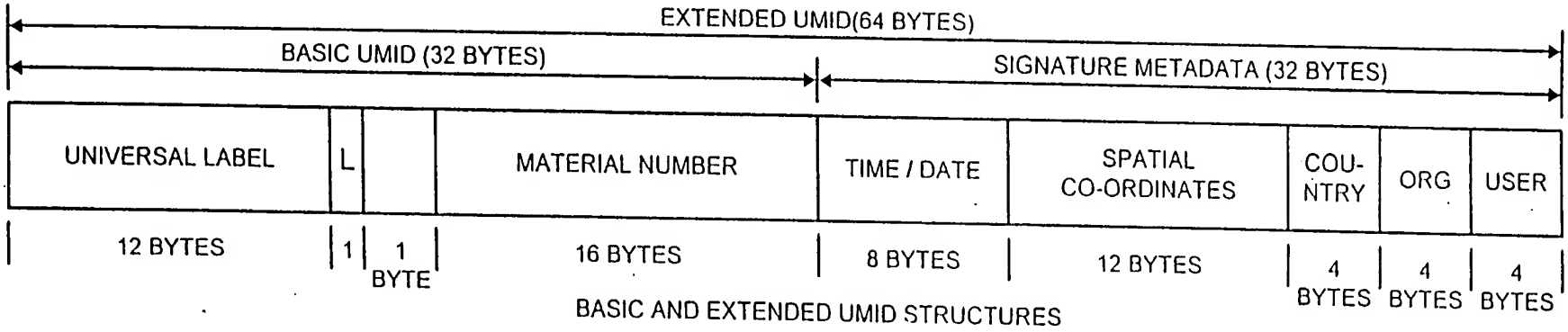


FIG. 9A



BASIC AND EXTENDED UMID STRUCTURES

FIG. 9B